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1992 TRDI CONFERENCE ON MILITARY R&D RESULTS

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SCIENCE & TECHNOLOGY
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1992 TRDI CONFERENCE ON MILITARY R&D RESULTS

93FE0340 Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p i-24

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1992 TRDI Conference on Military R&D Results

93FE0340A Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 pp i-iv

[Text] **Table of Contents**

Time: 10 November 1992 (Tuesday)
Place: TRDI HQ Lecture Hall

Estimation of Combustion Temperature of Liquid Propellants Using Spectrometric Methods

93FE0340A Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 1

[Article by Shiro Kushima and Hideaki Mukai, staff members, Firearms Research Office, Bureau 1, First Research Center, TRDI]

[Text] 1. **Objective**

To attempt to estimate the internal temperature of the combustion chamber during injection of liquid propellants by analyzing the spectrum of the combustion flash and measuring the distribution of intensity by wavelength (spectrometric method), and to the results with measurement by conventional radiant temperature measurement.

2. Methods Used and Content

The liquid propellant is injected into a high-temperature, high-pressure environment obtained by combustion of line explosive. The combustion flash after injection is measured by means of the test equipment shown in Figure 1, and the intensity of combustion flash is measured for each wavelength. The combustion temperature is calculated on the assumption that the intensity distribution follows Planck's law.

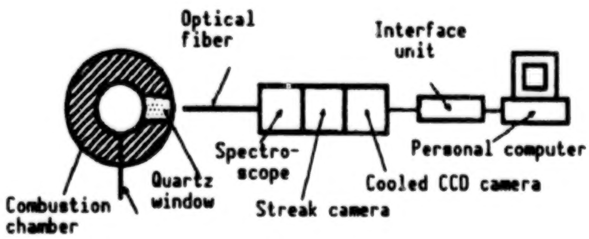

Figure 1. Block Diagram of Test Equipment

3. Results and Observation

(1) Results

The observed data and approximation curve shown in Figure 2 were obtained, and from those were derived the temperature calculations shown in Figure 3. Combustion of propellant is accompanied by chemical luminescence other than the black body radiation; to eliminate the effect of that, data was used only from the wavelengths (490~508 nm and 696~714 nm) where there was little effect from the luminescence, and combustion temperature was estimated using the

least-squares method. That data was then used to find ambient temperature at time of injection of liquid propellant and combustion temperature at time of peak combustion of liquid propellant, as shown in Figure 4.

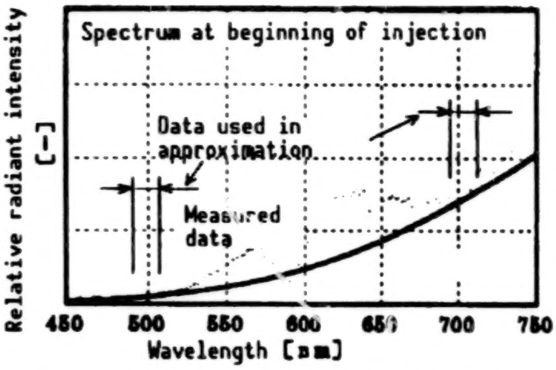

Figure 2. Sample of Measured Data

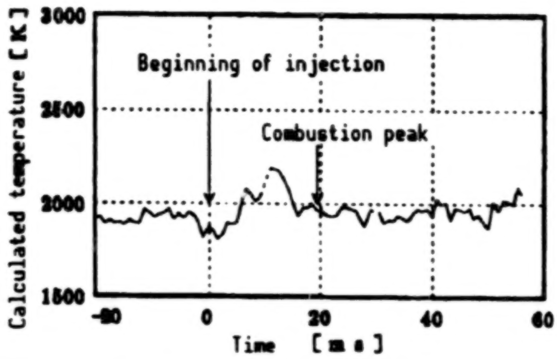

Figure 3. Calculation of Temperatures by Spectrometric Method

(2) Observations

This measurement was calculated with the interior of the combustion chamber regarded as a grey body; judging from the calculated results, that appears to be a correct hypothesis for measurement of high ambient temperatures. Near the time of peak combustion of the liquid propellant, the flash is dominant, and measurement by this formula becomes difficult. Based on test results, the proportion radiated by propellant combustion gases is thought to be 0.08~0.11 between 1800~2100 K.

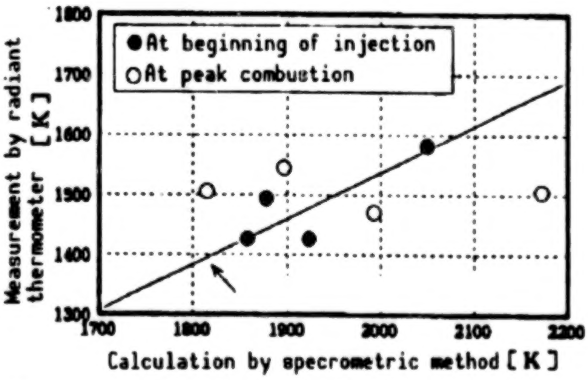

Figure 4. Comparison of Temperatures by Method of Measurement

Stabilized Nitrocellulose, LOVA Propellants

93FE0340B Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 2

[Article by Haruyuki Arisawa, Junichi Kimura, Toshihiko Shimizu and Tsuneo Koura, staff members, Ammunition Research Office, Bureau 1, First Research Center, TRDI]

[Text] 1. **Objective**

Conventional propellants consisting primarily of nitroglycerine and nitrocellulose have good combustion characteristics, but there are problems with their vulnerability to heat and shock; there have been numerous reports of secondary explosions in fires or when hit by a shell on the battlefield. There has been, therefore, strong demand for propellants that have LOVA (low-vulnerability ammunition) properties in addition to conventional properties. The LOVA properties of conventional nitrocellulose propellants have been improved by physically mixing in heat-resistant materials (such as cellulose acetate butylate, CAB). This office has attempted to reduce combustibility chemically by replacing some of the nitrate ester groups in nitrocellulose with less-combustible acetyl groups. The objective of this research has been to fabricate cellulose acetate nitrolate (CAN), investigate the basic properties of CAN by itself and its fundamental sensitivity and combustion properties when formed into a propellant, and to compare it with conventional propellants.

2. Methods Used and Content

The samples used in this research were nitrocellulose (NC) with a nitrogen content of 12.6%, and three varieties of CAN with the degree of acetylation varied from 0.7~2.0, used alone and formed as a propellant by adding such things as RDX. The temperature stability of simple NC and CAN were evaluated using thermogravimetry and differential scanning calorimetry (DSC). The samples formed into propellant underwent tension and compression tests, drop sensitivity tests and sealed bomb tests, and the LOVA properties and combustion properties were compared with a general triple-based propellant (M30A1).

3. Results and Observations

(1) Results

Figure 1 plots, using the Ozawa method, the peak temperature and rate of heating of CAN with a 2.0 degree of acetylation and of NC, as shown by differential scanning calorimetric analysis. The black triangles in the Figure are where it was determined samples ignited, from the exothermic peak. Figure 2 shows the results of drop sensitivity tests of three types of CAN propellant and M30A1 with NC as a binder. Figure 3 shows the pressure index of combustion speed, across a temperature range from -30~50°C, of a propellant with CAN having a 0.6 degree of alkylation as a binder and M30A1 propellant.

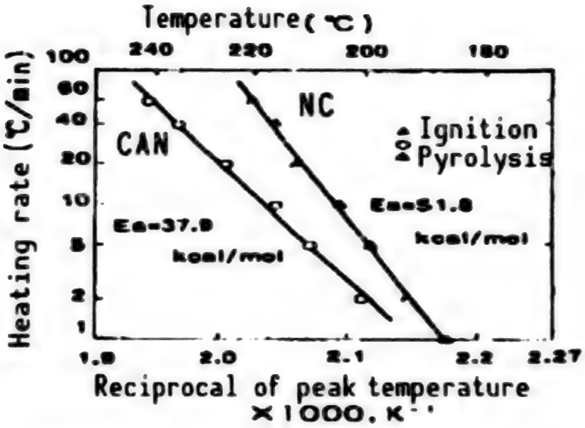

Figure 1. DSC Data for CAN and NC

(2) Observations

Figure 1 shows that, compared with NC that ignited at heating rates of 20°C and above, CAN did not ignite at the temperatures measures, and had become less combustible than NC. The activation energy of NC is about 52 kcal/mol, but that of CAN is only about 38 kcal/mol, indicating high temperature-resistance when heated at high rates.

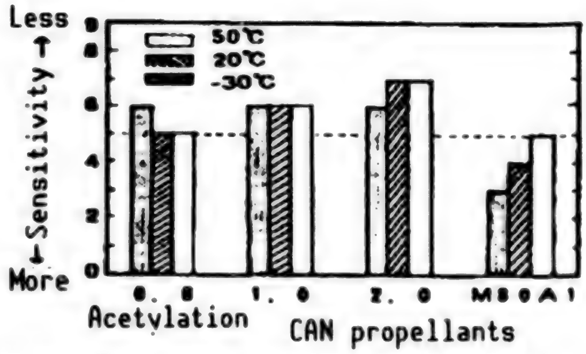

Figure 2. Comparison of Drop Sensitivity in CAN Propellants

Figure 2 confirms that the drop sensitivity of CAN propellants is lower than that of M30A1 propellant, and decreases as alkylation increases. Moreover, because of the relationship between drop sensitivity and firing sensitivity that we reported last time, it can be assumed that CAN has adequate LOVA properties in terms of firing sensitivity as well.

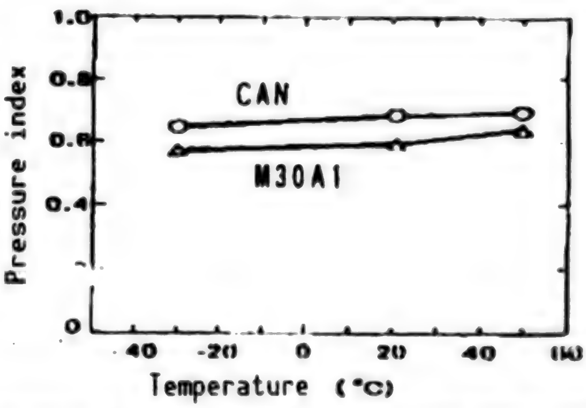

Figure 3. Pressure Index Dependence on Temperature in CAN and M30 Propellants

Figure 3: propellants consisting primarily of conventional nitroamine compounds have problems in terms of combustion properties, because of pressure indices in excess of 1.0. It can be seen from Figure 3, however, that when nitroamine propellants are used with CAN as a binder, the pressure can be suppressed to the same level as M30A1.

Judging from the results above, it is thought that use of CAN as a binder can provide satisfactory results both in combustion properties and LOVA properties, and that it will be possible to developed propellants that meet specific requirements by varying the proportion of alkyl groups within the molecule.

Spallation in Steel (Spallation Damage in Flat Plate Impact Test)

93FE0340C Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 3

[Article by Toshikatsu Mayama, staff member, Armor Systems Research Office, 2nd Bureau, First Research Center]

[Text] **1. Objective**

The damage phenomenon when shock waves cause cracks in metal materials is called spallation, and the behavior of the damage is known to vary with the material. With the advance of mathematical simulation technology in recent years, however, the spallation behavior for various structures has been explicated by means of numerical calculations, and it has become necessary to induce spallation artificially, inspect the damaged areas and acquire the damage parameters.

For this report, spallation damage cause in flat impact tests received macroscopic and microscopic examination, and the nature of spallation damage was considered.

2. Methods Used and Content

To produce ideal spallation, it is necessary to use a test system that will produce flat shock waves. For that reason, we used a procedure called the flat plate impact test devised in the late 1950s to measure Ugonio properties (see Figure 1). Soft recovery was necessary so that the samples would not be deformed except by the phenomenon under study, so it became necessary to study and improve recovery methods that would minimize deformation.

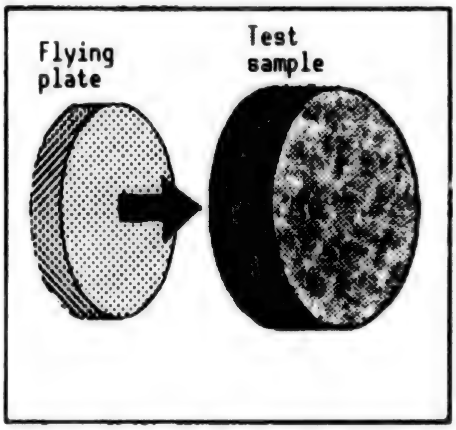

Figure 1. Flat Plate Impact Test

3. Results and Observations

(1) Results

Origin analysis based on earlier soft recovery data was performed, the origins of sample deformation during soft recovery were hypothesized, and countermeasures were devised. Most of the deformation of samples that occurred during soft recovery was prevented as a result, and mutual examination with simulation results could be done easily (see Figure 2 [not reproduced]).

Macroscopic and microscopic examination of the damaged surface and cross section of the damage was done for three materials: SM-41B, SS-41 and rotor material (used for steam turbines). As a result it was determined that exfoliation in the damaged cross section was as great as for materials with low static material strength. The most important result was that while there were numerous cracks in the SM-41B in multiple layers, cracks in SS-41, which is a similar material, was clearly demarcated in one or two layers (see Figure 3 [not reproduced]). Moreover, it was determined through observation at high magnifications that spallation cracking is a matter of connection of very small voids.

(2) Observations

The samples and observation results were all of low-strength materials, but it was possible to obtain useful, basic data about the nature of spallation damage. Various materials will be analyzed hereafter; this is expected to assist in explication of the phenomenon of penetration damage.

Generating Very High Pressure With Shock Wave Convergence

93FE0340D Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 4

[Article by Hiroshi Kunishige, staff member, 1st Armor Research Office, Bureau 2, First Research Center]

[Text] **1. Objective**

The flying plate impact method, in which gunpowder or explosives are used to make a flying metal plate collide with a target, yields high dynamic pressure, and so has been used in research to decide such things as solid state equations. There are limits, however, to the acceleration of the flying plate by increasing the amount of explosive, and consequently there are limits to the impact pressure that can be obtained. For that reason, there has been research on methods to generate high pressure by convergence of shock waves, as an effective method to obtain high dynamic pressure. For example, in the gun barrel flying plate impact method, we have done experimental research to concentrate shock waves above the central axis of a target with two-layer, cylindrical structure with an outer cylinder of aluminum alloy and an inner rod of copper. In this system, the shock wave propagated through the outer cylinder travels faster than the shock wave propagated through the inner rod, there is conical convergence toward the center, and a high pressure domain called a Mach disk is generated around the central axis.

In this research, we have surveyed traces of Mach disk generation by doing shock recovery experiments with the mousetrap method against the two-layered, cylindrical target. We have also investigated shock wave convergence, the mechanism that generates the Mach disk, by doing mathematical simulations.

2. Methods Used and Content

(1) Shock recovery experiment

The shock recovery experiment was done with the mousetrap flat shock wave generator and momentum trap sample recovery system illustrated in Figure 1. The recovery sample has a two-layered, cylindrical structure with 2024 aluminum alloy as the outer cylinder an internal rod consisting of

either 1) high-grade iron or 2) a SUS304 capsule filled with a mixture of powdered copper and graphite. The speed of the shock wave was measured at 2.1 km/s by the pin contact method.

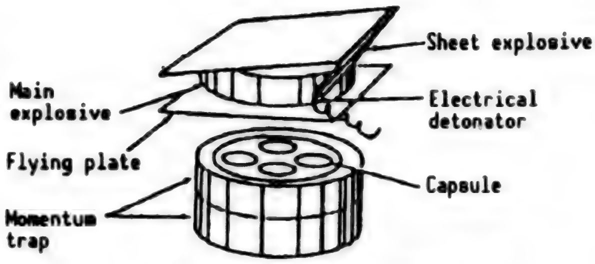

Figure 1. Mousetrap Flat Shock Wave Generator and Momentum Trap Sample Recovery System

(2) Mathematical simulation

Mathematical simulation of the shock recovery experiment was done in order to investigate the mechanism for Mach disk generation. The calculation code used was the two-dimensional shock analysis code, PISCES 2DELK.

3. Results and Observations

(1) Results

As a result of the shock recovery experiment, traces of high-pressure shock compression were found in the high-grade iron and the mixture of powdered copper and graphite. Figure 2 [not reproduced] shows a cross section of a sample with an inner rod of high-grade iron and an outer cylinder of 2024 aluminum alloy. A streamlined region was found that is regarded as showing phase transition, due to the high pressure along the central axis. This result matches, qualitatively, the mathematical simulation. It was also possible to understand the circumstances of Mach disk generation by means of the mathematical simulation.

(2) Observations

The method of generating high pressure by shock wave convergence can be applied to measurement of dynamic properties using shock gun experimental equipment. Moreover, the pressure generated can be further enhanced by the combination of inner rod and outer cylinder materials in a two-layered, cylindrical structure. The selection of materials and the optimum design for the two-layered, cylindrical structure are topics for further study.

Research on Surface Robot Technology (Perception of Environment Using Nontactile Sensors)

93FE0340E Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 5

[Article by Takao Okui, staff member, Mamoru Furuta, researcher, and Yoshihiro Naito, staff member, 4th Machinery Office, Department 1, Fourth Research Center]

[Text] **1. Objective**

To obtain technical data on environmental perception of terrain forms and obstacles, as element technology for realization of a newly proposed staged structure system for robots that move independently over uneven terrain.

2. Methods Used and Content

(1) Research to achieve the above objective was done by fitting a model robot with a CCD camera and laser range finder as non-contact sensors for perception of the environment.

(2) In this research, the robot's understanding of the environment was divided into the following four stages. In the first stage, uneven terrain is detected. In the second stage, uneven terrain is learned. In the third stage, the distinction is made between even terrain, passable uneven terrain, and obstacles (including impassible uneven terrain). In the fourth stage, the shape of the uneven terrain is understood.

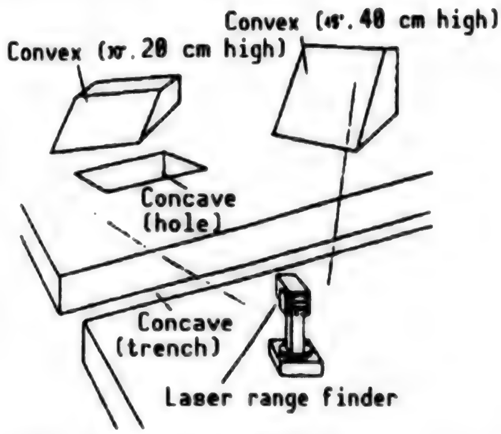

Figure 1. Experimental Model of Uneven Terrain

A basic model of uneven terrain was made in the laboratory using wooden blocks as shown in Figure 1. Experimentation was done, in the first stage, to create a detection algorithm for the color image data obtained from the CCD camera, and in the second stage, to create a learning algorithm from range image data obtained from the range finder.

3. Results and Observations

(1) Results

It was possible to detect uneven terrain by extracting color, physical boundary, and changes thereof from the image data obtained from the CCD camera. By means of preprocessing (including interpolation) and division processing of the distance image information obtained from the laser range finder, it was possible to learn the uneven terrain as shown in Figures 2 [not reproduced] and 3. Those are the basic experimental results obtained.

ID No.	Classification	θ left (deg)	θ right (deg)	Rnear (cm)	Rfar (cm)	H(max) (mm)	D(max) (mm)
1	CONCAVE	-30	30	48	105	-	215
2	CONVEX	-23	-7	169	199	191	-
3	CONCAVE	-22	-1	118	151	-	79
4	CONVEX	13	30	131	199	400	-

Figure 3. Results of Extraction of Landform Information

(2) Observations

Further research in learning uneven terrain will be carried out using a laser range finder and an algorithm will be established. Moreover, by fusing the color image data and distance image data and combining the results with those from contact sensors, a higher level of terrain discrimination will be achieved, and third and fourth stage environmental perception technology will be established.

Research on Centrifugal Explosive Testing (Simulation of Formation of Craters in Sand by Surface Explosions)

93FE0340F Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 6

[Article by Hiroshi Yamaguchi, Kazuo Fujimoto, Takashi Ito, Masahiro Morishita and Captain Tomonari Nagaai, staff members, Fortifications Research Office, Bureau 1, Fourth Research Center]

[Text] **1. Objective**

Tests with live explosives to evaluate the resistance to explosions of underground defensive structures require large-scale engineering work, and a great investment of manpower and money. For that reason, attention has been paid to reduced scale explosion tests in the laboratory using small amounts of explosive in a centrifugal force field, which allow modeling of explosion tests of large amounts of explosive in real structures. This report deals with (1) confirmation of the utility of centrifugal explosion testing of crater formation by surface explosions, which is an important index for evaluation of the resistance to explosions of underground defensive structures and (2) a method of mathematical simulation to supplement the tests and gain understanding of the detailed behavior of real explosions.

2. Methods Used and Content

(1) Centrifugal explosion testing

The experiments were carried out in a test bunker packed with standard sand using a small centrifugal equipment capable of a maximum 50 G centrifugal acceleration. The explosive was tetryl in four different quantities (0.12 g, 0.61 g, 1.46 g and 4.20 g including the detonator). The explosive was placed in the surface of the sand, and exploded when the desired centrifugal acceleration was achieved. Five levels of acceleration were used: 1 G, 10 G, 25 G, 35 G, and 50 G (in centrifugal explosion tests, when the reduction of scale is 1/N, the centrifugal acceleration is to be NG). The depth, diameter and volume of the crater formed were measured after each explosion.

(2) Mathematical simulation

The general-purpose code for collision phenomena (JDYNA3D) was used for mathematical simulation of a full-scale explosion corresponding to 0.61 g of explosive at a centrifugal acceleration of 50 G. The calculations modeled the formula for the state of standard sand and damage conditions based on past experimental data.

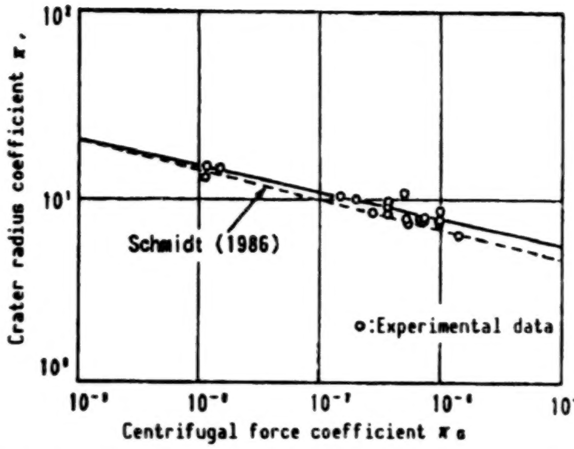

Figure 1. Relationship Between π_G and π_r

3. Results and Observations

Figure 1 illustrates the relationship between the centrifugal force field coefficient π_G (the pi number for gravitational acceleration and the energy of the explosive) and the crater radius coefficient π_r (the pi number for the radius of the crater). The tests confirmed that formula (1), which is shown by the solid line in the Figure, is analogous.

$$\pi_r \cdot \pi_G^{0.141} = 1.120 \quad \text{(correlation coefficient} = 0.910) \qquad (1)$$

Figure 2 illustrates a comparison between the mathematical simulation and test results of crater formation. Because it is difficult to express the dispersion of sand by an explosion in a mathematical simulation, the crater radii were smaller than in the tests, but crater depths were practically the same as in the tests.

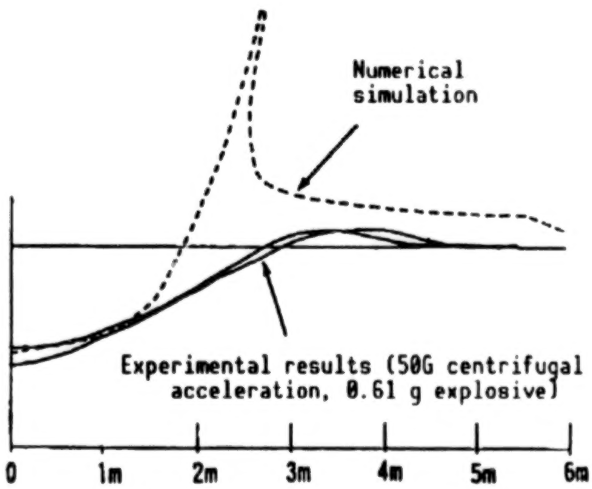

Figure 2. Crater Form

Research on Gas Turbines for Ground Vehicles (Simulation of Nonconstant Performance)

93FE0340G Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 7

[Art:cle by Yoichiro Shiwa and Soichi Uchida, staff members, 2nd Engine Research Office, Department 2, Fourth Research Center]

[Text] **1. Objective**

Gas turbines have the advantages of small size, light weight, high power and suitability to a variety of fuels; they have great promise as the engines for vehicles of the future. To make them practical, however, it is necessary to explicate engine and transmission control matching characteristics suited to the operating conditions for the vehicles. As the first stage of that process, it is important to explicate gas engine control technology for vehicles. First, it is necessary to know the dynamic characteristics (nonconstant performance) of engines, and to properly explicate simulation technology, including dynamic characteristics, for gas turbine engines for vehicles.

The objective of the present research is to contribute to the optimized design for gas turbine engines for future vehicles through explication of that simulation technology.

2. Methods Used and Content

In this research, a model for hypothesis of nonconstant performance of a gas turbine engine for vehicles was created on the basis of a gas turbine engine of the biaxial free turbine type, with a general purpose heat exchanger. Experimental data from a gas turbine pilot vehicles built for research purposes from FY88 to FY89 was used to verify the suitability of that model. In this model, the characteristics of the components making up the pilot vehicles were shown as mathematical models, and matching was attempted.

3. Results and Observations

(1) Results

There was a good match between the results calculated by the simulation model and the data from acceleration experiments with the pilot vehicles.

(2) Observations

This model can be applied, approximately, as a means for estimating acceleration characteristics of the pilot vehicles. This model will also provide useful data for the optimized design of gas turbine engines for future vehicles.

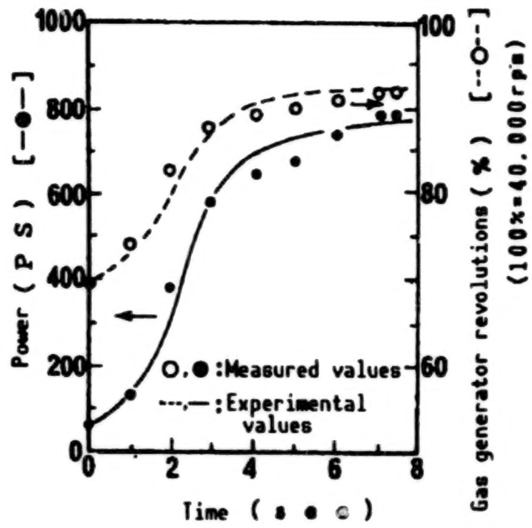

Figure. Acceleration of Pilot Vehicle

We plan to apply operating test data from tracked versions of the pilot vehicle to this model, and to improve the precision of the model by changing the technology level in regard to such things as the thermal resistance limits of the model.

XF3-400 Reheating Turbo Engine

93FE0340H Tokyo TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE, DEFENSE AGENCY in Japanese Nov 92 p 8

[Article by: Iwao Kashiwagawa, Shunichi Sakuma, Major Mitake Igarashi, Masakore Kitamura and Hidekatsu Kikuchi, staff members, 1st Engine Research Office, Bureau 2, Third Research Center]

[Text] **1. Objective**

A research version of the XF3-400 reheat turbofan engine was fabricated to obtain basic research information on engines for fighter aircraft. The engine was delivered at the end of FY91, and is now being tested within TRDI. This report provides an overview of the XF3-400 engine that has been fabricated.

2. Methods Used and Content

The basic guideline devised for fabrication of the engine was to start with the development technology for the F3 engine for the T-4 intermediate trainer, to add the results of subsequent element research, and to consider these points: a) increasing the overall specific pressure and combustor temperature, b) mounting control equipment and accessories that use digital electronic controls (FADEC) for engine control, and c) reducing engine weight.

The outside diameter of the engine is about the same as that of the F3-30, and new (advanced) technology was incorporated as constituent element technology.

3. Results and Observations

(1) Results

Major engine specifications are shown in the following table. The marked numbers (*) are design values. This engine is the first to be produced in Japan with reheat (afterburner) equipment and digital electronic control equipment with hydraulic backup.